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Comparing Bedside Methods of Determining Placement of Gastric Tubes in Children

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Abstract

Purpose—The purpose of this study was to compare the accuracy and predictive validity of pH, bilirubin, and CO2 in identifying gastric tube placement errors in children.

Design and Methods—After the tube was inserted into 276 children, the CO2 monitor reading was obtained. Fluid was then aspirated to test pH and bilirubin.

Results—Lack of ability to obtain tube aspirate was the best predictor of NG/OG placement errors with a sensitivity of 34.9% and a positive predictive value of 66.7%. Measuring pH, bilirubin, and CO2 of tube aspirate was less helpful.

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Practice Implications—Health care providers should suspect NG/OG tube misplacement when no fluid is aspirated.

Search Terms

Nasogastric tube; pH; CO_2 monitoring; bilirubin; children

Insertion of a gastric tube (nasogastric [NG] or orogastric [OG]) is a common medical intervention in children for a wide range of clinical indications, including delivery of enteral nutrition, administration of medications, decompression of the stomach following intestinal obstruction or surgery, irrigation of the stomach, and performance of diagnostic procedures (Phillips, 2006). When the gastrointestinal (GI) tract is intact and the need for assisted feeding is expected to be short-term, feeding by an NG/OG tube is preferred over feeding through a gastrostomy tube (Kirby, Delegge, & Fleming, 1995). Small-bore NG/OG tubes are usually used for enteral nutrition because they are made of soft polyurethane that remain flexible when exposed to gastric acid; thus, patient discomfort is reduced (Sriram, Jayanthi, Lakshmi, & George, 1997). Small-bore NG/OG tubes also reduce the risk of aspiration because the smaller diameter does not affect the competency of the lower esophageal sphincter as much as large-bore tubes (Phillips, 2006; Sriram et al., 1997); however, small-bore tubes are known to be misplaced on insertion and to displace during use (Ellett & Beckstrand, 1999; Ellett, Maahs, & Forsee, 1998; Metheny, 1988; Williams & Leslie, 2004).

Problem

Nurses have the responsibility to ensure correct gastric tube placement; however, high quality prospective pediatric studies of commonly used beside assessment methods are lacking, so no pediatric norms have been established. Ensuring safe and effective feeding via gastric tubes requires achieving and maintaining correct tube placement (Ellett & Beckstrand, 1999). Tubes are improperly placed if the feeding openings are located in the respiratory tract, esophagus, or past the pylorus (Khilnani, 2007). Preliminary studies in children show that between 21% and 44% of these tubes are placed incorrectly (Ellett, 1997; Ellett et al., 1998). When tubes are out of place, children can be seriously harmed, causing increased morbidity and occasionally death. It is important to assess children directly rather than apply adult norms because children requiring NG/OG tubes for feeding tend to be premature infants or infants with immature and smaller body systems, which increases the chance of a tube placement error and may lead to differences in norms for placement detection.

Purpose

The primary purpose of this study was to estimate and compare the accuracy and the predictive validity of two bedside methods (pH and bilirubin), individually and in combination, in identifying tube placement errors at insertion in children. A secondary aim was to explore the use of carbon dioxide (CO_2) monitoring to detect unsuspected tube misplacement into the respiratory tree during insertion. The results of this study will add to the body of knowledge being developed regarding assessment of NG/OG tube placement specific to children.

Review of Literature

Methods of Testing Tube Placement

There have been multiple bedside methods of gastric tube placement verification recommended in the literature, including (a) observing the patient for signs of choking, coughing, dysphagia, and lack of the ability to speak (cry in infants) during insertion; (b) looking for bubbling from the open end of the tube when held under water; (c) auscultation of insufflated air; (d) measuring the distance from the nose/mouth to the proximal end of the tube; (e) testing pH of tube aspirate; (f) measuring bilirubin of tube aspirate; (g) measuring pepsin and trypsin of tube aspirate; (h) observing the color and consistency of tube aspirate; and (i) measuring CO_2. Because of space limitations, only literature regarding the three methods that were tested in the current study will be reviewed. Initial research on determining gastric tube placement was conducted with adults. Under each subheading below, we briefly present the pertinent adult literature followed by the available pediatric literature.

Obtaining Tube Aspirate

Characteristics of aspirate may help discriminate between stomach and intestinal placement; however, it may be impossible to obtain fluid even when the tube is properly placed in the GI tract if the most proximal orifice is not in a pool of fluid. Furthermore, aspiration of fluid may be difficult because flexible small-bore tubes tend to collapse when negative pressure is applied with a syringe (Crocker, Krey, & Steffee, 1981; Rombeau & Barot, 1981); therefore, the absence of fluid is not necessarily evidence of improper placement. On the other hand, in a cross-sectional study, Metheny and coresearchers (1989) were able to aspirate sufficient fluid for pH testing from 92.5% of NG and 91.8% of nasointestinal (NI) tubes in 181 adults after injection of 30 mL of air. Likewise in a cross sectional study, Ellett, Croffie, Cohen, and Perkins (2005) were able to aspirate sufficient fluid for pH testing in 94.4% of NG/OG/NI tubes already in place in 72 children after injection of 1–5 mL of air.

Testing pH of tube aspirate—pH testing is based on the premise that fluids aspirated from different locations within the body have different mean pH values. Measuring pH is considered to be effective in distinguishing between respiratory and gastric aspirates and between gastric and intestinal aspirates because gastric pH is lower than the pH of respiratory or intestinal aspirates (Metheny, Smith, & Stewart, 2000). A pH ≤ 5 indicates gastric placement in fasting adults, and a pH ≤ 6 indicates gastric placement in fed adults (Metheny et al., 1993; Metheny et al., 2000).

In a cross-sectional descriptive study involving 53 critically ill children, the mean pH of pre-pyloric tube aspirates was 4.4 compared to a mean pH of 6.9 in post-pyloric tube aspirates in children receiving no H_2 receptor blockers or proton pump inhibitors (Gharpure, Meert, Sarnaik, & Metheny, 2000). Similarly in a cross-sectional descriptive study, Metheny, Eikov, Rountree, and Lengettie (1999) found the mean gastric pH to be 4.3 compared to a mean intestinal pH of 7.8 in 39 acutely ill neonates. In a descriptive study of 39 children with NG/OG/nasointestinal tubes followed longitudinally, pH of tube aspirate predicted both correct (negative predictive value [NPV] 69.2%) and incorrect (positive predictive value

[PPV] 42.8%) tube placement better than other bedside methods tested, including auscultation (Ellett & Beckstrand, 1999).

The pH method cannot be used to differentiate between respiratory and intestinal placements; however, because both typically result in aspirate pHs > 5. Also, up to 15% of gastric samples in two cross-sectional studies involving adults were shown to have a pH > 6 (Metheny et al., 1993; Metheny, Stewart et al., 1999). The pH of tube aspirate is not predictive when the tube is located in the esophagus because the presence of gastro-esophageal reflux (GER) may lead to either acidic or alkaline readings (Khilnani, 2007).

It is estimated that one fourth to one half of all infants will manifest symptoms of GER up to 6 months of age (Gastroesophageal Reflux Report of 76th Ross Conference on Pediatric Research, 1979). The lower esophageal sphincter (LES) is a zone of muscular thickening running diagonally from the lower right to the upper left. This high pressure zone rhythmically constricts the esophagus with each diaphragmatic respiratory movement (Liebermann-Meffert, Allgower, Schmid, & Blum, 1979). GER is more common in infants because the LES is short (only 1 cm in length compared to 3–4 cm in adults) and the angle of HIS (angle between the esophagus and the fundus of the stomach) is obtuse during the first 5–7 weeks after birth and gradually becomes more acute thereafter (Hollwarth & Uray, 1985; Muller Botha, 1958; Reyes, Ostrovsky, & Radhakrishnan, 1982).

Combined pH and bilirubin testing of tube aspirate—Metheny, Stewart and co-researchers (1999) recommended that a combination of pH and bilirubin levels of aspirates be used to differentiate gastric, intestinal, and respiratory placements of tubes. This recommendation remains the standard today (Cincinnati Children's Hospital Medical Center, National Guidelines Clearinghouse, Agency for Healthcare Quality & Research, 2011). Metheny and colleagues (1999) measured pH and bilirubin of aspirates obtained from 209 NG and 228 NI tubes in fasting, acutely ill adults who then received radiographs to determine the internal location of the tube. They also supplemented the one respiratory placement by testing pH and bilirubin levels in 125 tracheobronchial suction and 24 pleural fluid aspirates. Mean bilirubin levels were 0.09 mg/dL (tracheobronchial/pleural), 1.28 mg/dL (stomach), and 12.73 mg/dL (intestine). The combination of pH and bilirubin was highly sensitive to respiratory placement; it correctly identified 100% of respiratory aspirates. The test had a slightly lower specificity for non-respiratory placements correctly identifying 85.9% of actual non-respiratory aspirates. The positive predictive value of the test was problematic for respiratory placements because only 29.4% predicted respiratory aspirates were actual respiratory placements. The negative predictive value of 87.7% of true non-respiratory placements being accurately predicted as non-respiratory was higher (Metheny, Stewart et al., 1999). In a more recent study of 80 fed adults, Metheny and Stewart (2002) concluded that a bilirubin concentration of ≥ 5 mg/dL was a good predictor of intestinal tube placement; whereas, a bilirubin concentration of < 5 mg/dL was a good predictor of gastric tube placement whether or not the adult was fasting. Bilirubin can be easily measured at the bedside using the method developed by Metheny and co-researchers (2000) in which urine reagent strips are compared to a color scale specific for gastric fluid.

In a previous study of gastric bilirubin levels in children, Metheny, Eikov and co-researchers (1999) found little bilirubin (mean 0.35 ± 0.10 mg/dL) in 90 aspirates from 39 neonates. Ellett and co-researchers (2005) studied the ability of CO_2 monitoring and pH and bilirubin testing of tube aspirate to predict NG/OG tube placement in the stomach in 72 children ages 7 years and younger and found only measuring pH was useful in making decisions. The researchers stated that an algorithm assuming gastric placement if the pH of tube aspirate was < 5 would have theoretically resulted in 92% accuracy.

Observing the color and consistency of tube aspirate—In a study of 880 feeding tube aspirates in adults, Metheny, Reed, Berglund, and Wehrle (1994) found that visual characteristics of gastric aspirates were usually cloudy and green, tan or off-white, or bloody, or brown. The brown color comes from the action of gastric acid on blood (Westhus, 2004). Intestinal aspirates were usually clear and yellow or deep golden yellow (i.e., bile stained). If not bloody, pleural fluid was usually serous and pale yellow and tracheobronchial secretions were mucousy and tan or off-white (Metheny et al., 1994). In her study of 56 children, Westhus (2004) found the colors of 41/49 (83.6%) of gastric aspirates were colorless, green, off-white, or brown; while 5/7 (71.4%) of intestinal aspirates were yellow or bile-stained.

Measuring CO_2

The detection of CO_2 at the distal end of NG/OG tubes to ascertain unsuspected respiratory placement has been investigated and found to be 100% accurate in 10 critically ill adults. However, this method has not been adopted in practice nor adequately tested in children (Araujo-Preza, Melhado, Gutierrez, Maniatis, & Castellano, 2002; Ellett et al., 2005; Thomas & Falcone, 1998).

In summary, problems associated with these and other techniques have led to ongoing discussion in the literature regarding method validity (Phillips, 2006). Several descriptive studies of various bedside methods generally involving large sample sizes have been tested in adults mainly by one research team. On the other hand, only a few descriptive studies by several researchers involving small sample sizes have been done in children. Based on available research, consensus holds that more than one method of monitoring the placement of NG/OG tubes at the bedside should be used and an abdominal radiograph should be obtained if there is any doubt that the tube ends in the stomach (Ellett, 2004; Ellett et al., 2011; Ellett et al., 2012; Grant & Martin, 2000; Metheny & Titler, 2001; Sanko, 2004) because radiology is commonly viewed as the “gold standard” for accurately determining the internal location of NG/OG tubes in adults and children (Ellett, 2004; Metheny & Titler, 2001).

Methods

Design

This article draws upon data from a larger study. This larger study, the first pediatric study in which NG/OG tubes were inserted as part of a study, was a single-blind, randomized controlled trial. The children were randomly assigned to have their NG/OG tube inserted using one of the three insertion-length predictors: age-related, height-based regression equations; direct distance nose-ear-xiphoid; or direct distance nose-ear-mid-umbilicus. A stratified block randomization was used in which stratification was by use of acid-inhibiting medication (yes, no) and age group (< 1 month, 1–28 months, 29–100 months, and 101–215 months). The results of this part of the study, which indicated that the nose-ear-mid-umbilicus distance and height-based regression equations for three age groups were equally good in predicting the distance to insert NG/OG tubes have been reported elsewhere (Ellett et al., 2011; Ellett et al., 2012). In all children, tube placement was tested at the bedside by monitoring CO_2 and testing pH, and bilirubin of tube aspirate. Although not a primary or secondary aim, the color and consistency of tube aspirate was also collected because it is standard practice to examine these parameters. Results of analysis for these cross-sectional and descriptive tube aspirate data are reported herein.

Recruitment

Two-hundred seventy-six children (24 weeks gestation to 212 months of age) were recruited from five Midwestern hospitals. All children hospitalized on one of the participating units requiring an NG/OG tube to be inserted were eligible unless: (a) their staff physicians refused to allow researchers to approach the family about the study; (b) their medical conditions could drastically affect their gastric acid-secreting ability (e.g., Zollinger-Ellison Syndrome or congenital achlorhydria); or (c) they had had previous gastric surgery resulting in removal of part of the stomach.

Procedures

This study was approved by the appropriate institutional review boards and the hospitals/units in which the study was conducted. Two research associates were trained in all aspects of data collection by the principal investigator (PI, first author) using a written protocol. They collected 76% of the data. Other research nurses were trained by the two research associates using the same protocol and collected the remaining 24% of the data. The PI evaluated and approved each nurse prior to him/her being allowed to collect data independently. Inter-rater reliability was collected between each trained data collector and the PI, approximately every fifteenth child per data collector. Parent(s)/guardian provided written informed consent, and children ages 7 years or older provided assent when cognitively able.

After the NG/OG tube was inserted using the randomly assigned insertion-length predictor distance by either the research nurse in most children or the nurse caring for the child in a few neonates, the tube was temporarily taped in place. S/he then attached the CO_2 monitor (Novametrix Capnography, Tidal Wave, Wallingford, CT) to the open end to detect unsuspected respiratory placement. The CO_2 monitor was left in place until the reading was stable for at least 1 minute. Next, fluid was aspirated from the tube to test pH using a pH meter (Beckman Coulter pHi 410, Indianapolis, IN) until a stable reading was obtained and also a pH paper (pHydrion™ Insta-chek 0–13, Micro Essential Laboratory, Brooklyn, NY) according to manufacturer’s recommendations. The minimal amount of fluid needed to test pH using the pH meter was 0.1 mL, and only a drop was needed to use the pH paper. Then, a drop of aspirate was used to test for bilirubin using a urobilinogen test strip (VWR Urine

Reagent Strips, VWR International, West Chester, PA) and compared within 30 seconds to the bilirubin results from a colorimetric visual bilirubin (VBIL) scale developed specifically for GI secretions by Metheny, Stewart et al. (1999). The remainder of the aspirate was sent to the laboratory for a bilirubin level. The color and consistency of the tube aspirate were also recorded. Acid-inhibiting medication use was obtained from the child's medical record.

Within 45 minutes (in 95% of children) after placement of the tube, an abdominal radiograph was obtained to show the internal location of the tube. Once the radiograph was read by a pediatric radiologist, physician, or pediatric nurse practitioner (based on unit policy) using their normal criteria, the tube length was adjusted as necessary based on the healthcare provider's recommendation prior to use.

Radiographs

All radiographs taken after initial placement of the tube were reviewed at a later time by a single board-certified pediatric radiologist (second author). For each radiograph, the location of the tip of the tube was classified into one of four locations:

1. Tube tip in the esophagus (if the tube tip was in the esophagus, then it was noted if the lower end of the tube was straight or curled back on itself with the tip pointing towards the child's head),
2. Tube tip or visible openings in the region of the gastroesophageal junction (GEJ),
3. Tube tip and all visible openings in the stomach (goal), or
4. Tube tip in the pylorus or the duodenum.

Data Analysis

Analyses were performed using SAS® Version 9.3 software (Copyright (c) 2002–2010 by SAS Institute Inc.; Cary, North Carolina) unless otherwise specified. Descriptive statistics were calculated, including means and standard deviations for continuous variables, and frequency and percent in each category for categorical variables. Intra-class correlation coefficients (ICCs) were used to calculate inter-rater reliability between data collectors and agreement when comparing the pH as measured by the pH strip and pH monitor. A final pH to be used for analysis purposes was created by using the value from the pH monitor if available; otherwise, the value from the pH paper was used. Sensitivity, specificity, PPV, and NPV for non-stomach placement were calculated for the entire sample and each of two age groups (< 1 month [neonates] and ≥ 1 month [older children]) separately. The pH cutpoints used were Metheny and co-researchers' (1993) recommended pH cutoff of 5 in the fasting group (NPO ≥ 3 hours) and Metheny and co-researchers' (2000) recommended pH cutoff of 6 in the fed group (NPO < 3 hours). Similar statistics were calculated for the ability to obtain aspirate and for the color and consistency of the aspirate in addition to the color/pH combinations. Other pH cutoffs or aspirate color/consistency combinations were examined to determine if they would be more appropriate using classification tree methods using the RPART function of the statistical package R (R Development Core Team, 2011).

Results

Characteristics of the children participating in this study including gender, age, and race are presented in Table 1. Of note, children of minority ethnicity/race were well represented in this study with participation occurring at a higher rate than that of the population of the state in which the study was conducted.

Nutri-cath, Neo Devices, Argyle, Neocare, and Neo Med tubes were the most frequently inserted during this study accounting for 89% of tube placements. Sizes varied from 5–12 Fr. There were 63 (22.8%) tubes placed outside the stomach—26 in the esophagus, 23 in the GEJ, and 14 in the pylorus/duodenum. There were no unsuspected respiratory placements. It was noted that no aspirate was obtained from 33 children: 15/26 (57.7%) of NG/OG tubes ending in the esophagus, 7/23 (30.4%) of tubes ending in the GEJ, and 11/213 (5.2%) of tubes ending in the stomach. Conversely, aspirate was obtained in 41/63 (65.1%) non-stomach placements including all 14/duodenal/pylorus placements and in 202/213 (94.8%) stomach placements. Thus, if using lack of ability to obtain aspirate as an indication of misplacement, the sensitivity, specificity, PPV, and NPV would be 34.9%, 94.8%, 66.7%, and 83.1%.

pH

An adequate amount of aspirate was obtained for pH testing in 236/276 (85.5%) children using pH paper and in 135/276 (48.9%) children using the pH monitor. In 3 of the 135 children, sufficient fluid was aspirated to use the pH monitor, but it malfunctioned. The ICC measuring the agreement between the pH monitor and the pH paper was 0.76. Inter-rater reliability was ICC = 0.93 for 11 children for the pH paper and ICC = 1.00 for 5 children for the pH monitor. For neonates, the pH values ranged from 2 to 7 using the test paper and 0.6 to 6.8 using the monitor. The pH values for the older children ranged from 1 to 9 using the paper and 1.3 to 11.2 using the monitor. The child with the pH of 11.2 had congenital adrenohypoplasia and was receiving several medications that possibly affected the pH reading; however, because this could not be verified, we used this child's conservative pH paper reading of 7.0 for the analysis.

When Metheny and co-researcher's (1993) recommended pH cutoff of 5 was used in the 154 fasting children from which aspirate was obtained, the sensitivity (given NG/OG tube was not in the stomach on radiograph, pH was > 5) was 3/30 (10.0%) and the positive predictive value (given pH was > 5, the NG/OG tube was not in the stomach on radiograph) was 3/13 (23.1%). The specificity was 91.9% and negative predictive value 80.9%. Using Metheny and co-researchers' (2000) recommended pH cutoff of 6 for the 82 fed children, the sensitivity was 2/9 (22.2%) and the positive predictive value was 2/11 (18.2%; Table 2). The specificity was 87.7% and negative predictive value 90.1%. No better pH cutoff could be suggested using the classification tree method either in the overall sample or when dividing the sample by fasting versus fed. Figure 1 graphically depicts the pH for stomach and non-stomach placements by age group for fasting and non-fasting children. When considering the fasting children by age group, Metheny and co-researchers' (1993) pH cutoff of 5 resulted in sensitivities, specificities, PPVs, and NPVs of 8.7%, 92.2%, 20%, and 81.7% in the 125 neonates and 14.3%, 90.9%, 33.3%, and 76.9% in the 29 older children. Similarly, for fed children by age group Metheny and co-researchers' (2000) pH cutoff of 6 resulted in sensitivities, specificities, PPVs, and NPVs of 0%, 89.5%, 0%, and 89.5% in the 21 neonates and 28.6%, 87.0%, 22.2%, and 90.4% in the 61 older children.

Only 41/276 (14.9%) children in this study received an acid-inhibiting medication; pH of tube aspirate was available for 35 (85.4%). In the 235/276 (85.1%) children who were not receiving an acid-inhibiting medication, the pH of tube aspirate was available for 201 (85.5%). The mean pH was not significantly different between the two groups (acid-inhibiting medication: 3.9 [*SD* ± 1.5]; not receiving an acid-inhibiting medication: 3.8 [*SD* ± 1.4]; *p*-value = .71) and the distributions were very similar in shape. In addition, similar results were obtained when the analysis was stratified by in stomach/not in stomach. Thus, we do not report the results stratified by receiving acid-inhibiting medications; however, tables are available from the authors upon request.

Aspirate Color and Consistency

Tube aspirate was reported as white in 99/240 (41.3%), colorless in 51/240 (21.3%), tan in 40/240 (16.7%), yellow in 24/240 (10%), brown in 10/240 (4.2%), bloody in 8/240 (3.3%), green in 4/240 (1.7%), and other in 4/240 (1.7%) children. White, green, and tan colors in 143/240 (59.6%) children may indicate stomach placement. Yellow color may indicate placement in the pylorus/duodenum; whereas, colorless aspirate might indicate either esophageal or GEJ tube placement. Bloody aspirate could be from anywhere including outside the GI tract. Brown aspirate could either be old blood or bile staining, indicating duodenal placement. Using these categories of colors, 3/14 (21.4%) of tubes actually ending in the pylorus/duodenum would have been correctly identified and 11/14 (78.6%) tubes would have been mis-identified as not ending in the pylorus/duodenum. One hundred and twenty/200 (60.0%) tubes actually ending in the stomach would have been correctly identified and 80/200 (40.0%) would have been mis-identified as not ending in the stomach. Also, 8/26 (30.8%) tubes ending in the esophagus or GEJ would have been correctly identified and 18/26 (69.2%) tubes would have been mis-identified as not ending in the esophagus or GEJ (Table 3). The consistency of the tube aspirate was examined but not found to be helpful in predicting misplacement nor was using a combination of color and consistency. Data are not shown but are available upon request.

Combined pH and Color of Tube Aspirate

When pH and color of tube aspirate were combined in the 235 available samples (Table 3), the positive predictive value for tube placement error improved slightly. Using Metheny and co-researchers' (1993) recommended pH cutoff of 5 for fasting children, the sensitivity (given that the NG/OG tube was not in the stomach on radiograph, either the pH > 5 or the color was not white, green, or tan or both) was 12/30 (40.0%) and the positive predictive value (given that either the pH was > 5 or color was not white, green, or tan, or both, the NG/OG tube was not in the stomach on radiograph) was 12/48 (25.0%) in the fasting children. The specificity was 70.7% and negative predictive value was 82.2%. Using Metheny and co-researchers' (2000) recommended pH cutoff of 6 for fed children, the sensitivity (given that the NG/OG tube was not in the stomach on radiograph, either the pH > 6 or the color was not white, green, or tan, or both) was 6/9 (66.7%) and the positive predictive value (given that either the pH was > 6 or color was not white, green, or tan, or both, or the NG/OG tube was not in the stomach on radiograph) was 6/54 (11.1%) in the fed children. The specificity was 36.0%, and negative predictive value was 90.0%.

Bilirubin and CO_2

In this study, bilirubin, measured using the VBIL scale, and CO_2, had virtually no variability. Bilirubin was also measured in the laboratory and although the variation increased, it was still not helpful in predicting misplacement. Inter-rater reliability was also not assessed because of the lack of variability. Data are not shown but are available upon request.

Discussion

The primary aim of this study was to estimate and compare the accuracy and the predictive validity of two bedside methods (pH and bilirubin), individually and in combination, in identifying tube placement errors at insertion. As can be seen in Table 4, although the ability to use pH to detect stomach placement when the NG/OG tube is actually in the stomach consistently ranges from 87.0% to 92.2% (specificities), the ability to detect actual tube placement errors given they are predicted ranges from 0 to 33.0% (positive predictive value). In this sample of 276 children, 173 of which were less than 1 month of age, the mean pH of 3.9 (in children receiving an acid-inhibiting medication) and 3.8 (in children not receiving an acid-inhibiting medication) indicated that the children were able to generate an acid pH. It is possible that an increased incidence of incompetence of the LES in neonates allowing GER into the GEJ and esophagus resulted in pH values less than or equal to 5, which contributed to these low positive predictive values. Also, the tip of the tubes that were categorized as ending in the pylorus or duodenum on radiograph either ended in the pylorus or ended just into the duodenum, so the pores of the tube could have still been in the stomach. Using color of tube aspirate alone performed worse than measuring pH alone. Because healthcare providers are assessing placement at the bedside to detect tube placement errors, the PPV is the most important value to consider. The PPVs of pH (range 0 – 33%), color (17.5%), and the combination of pH and color (25%) of tube aspirate are not clinically adequate.

The superior method of identifying when the NG/OG tube ended in the stomach and when it did not was the inability to obtain any aspirate from the tube based upon its sensitivity (34.9%) and PPV values (66.7%). In hindsight, these high values might have been anticipated because tubes ending in the esophagus might only yield a small amount of mucus if anything unless GER was present, and once past the pylorus, peristalsis moves fluids through the small intestine relatively quickly.

While this study was in progress, the decision was made by manufacturers that the VBIL strips would not be produced commercially (verbal communication, Norma Metheny, 2006). A bilirubin cutoff of greater than or equal to 5 mg/dL was also found in this study as well as in a previous study by Ellett and co-researchers (2005) to not be helpful in predicting tube placement errors. This finding can be explained by the fact that the tip of the tubes ending in the pylorus or duodenum were not far enough into the duodenum to reach the Ampulla of Vater, where bile enters the duodenum.

A secondary aim was to explore the use of CO_2 monitoring to detect unsuspected tube misplacement into the respiratory tree during insertion. There was only one respiratory placement of an NG/OG tube in this study. The child demonstrated immediate symptoms and the tube was withdrawn before the CO_2 monitor could be attached. The fact that no unsuspected respiratory placements occurred either in this study or in a previous study by this research team (Ellett et al., 2005) supports the supposition that unsuspected respiratory placements in children are rare.

Limitations

Limitations of this study include the small sample sizes in some of the cells of the contingency tables. In addition, we determined our superior method in part based on PPV. PPV is a function of the prevalence of misplacement. Thus, our conclusions are most applicable to populations that have a similar prevalence of misplacement to our study. Also because there were no unsuspected respiratory placements, the use of a CO_2 monitor remains inadequately tested in children.

Implications for Research

The next logical study would be a cohort study involving a large sample of children whose NG/OG tubes are passed using either (or both) of the insertion-length predictors found to be superior for predicting the distance to insert the tube followed by assessing tube placement by attempting to aspirate fluid from the tube. If no aspirate is obtained, the child could be repositioned and/or the tube removed and reinserted. If no aspirate is obtained after these maneuvers, an abdominal radiograph could be done to determine tube placement and the position of the tube should be manipulated so that the tip and all openings are in the stomach. Then the children should be followed during their hospitalizations to determine how often tubes migrate from the stomach over time and whether these migrations are detected by inability to aspirate fluid from the tube. Recording the cost of implementing these interventions could be tracked to give healthcare providers objective data on which to base future policy decisions.

Measuring pepsin and trypsin in the laboratory could also be tested in a larger sample of children to determine if these enzymes will improve the accuracy of predicting tube placement errors both at the time of initial insertion or change of tube, and longitudinally during use of the tube. If so, then bedside tests for measuring pepsin and trypsin will need to be developed.

Also, new methods (electromagnetic or based on the stud-finding principle) of detecting the placement of the tip of nasointestinal tubes currently being studied may be able to be used to determine the location of NG/OG tubes as well.

How might this information affect nursing practice?

The Best evidence statement (BESt) Confirmation of Nasogastric/Orogastric tube (NGT/OGT Placement; Cincinnati Children's Hospital Medical Center, National Guidelines Clearinghouse, Agency for Healthcare Research & Quality, 2011) evaluates the evidence for practice on this topic with the most recent reference being 2009. Based on this guideline and results of studies published since then, including this study, healthcare providers should suspect NG/OG tube placement error whenever they are unable to aspirate fluid from the tube. The child should be repositioned and a second attempt made to aspirate fluid. Radiographic verification of tube placement should be sought in children at the time of initial NG/OG tube insertion and change, and in routine monitoring whenever no aspirate is obtained after implementing the measures suggested above (Ellett, 2004; Ellett et al., 2011; Ellett et al., 2012; Grant & Martin, 2000; Metheny & Titler, 2001; Sanko, 2004). This radiograph should be read by a healthcare provider prior to using the tube for any type of instillation.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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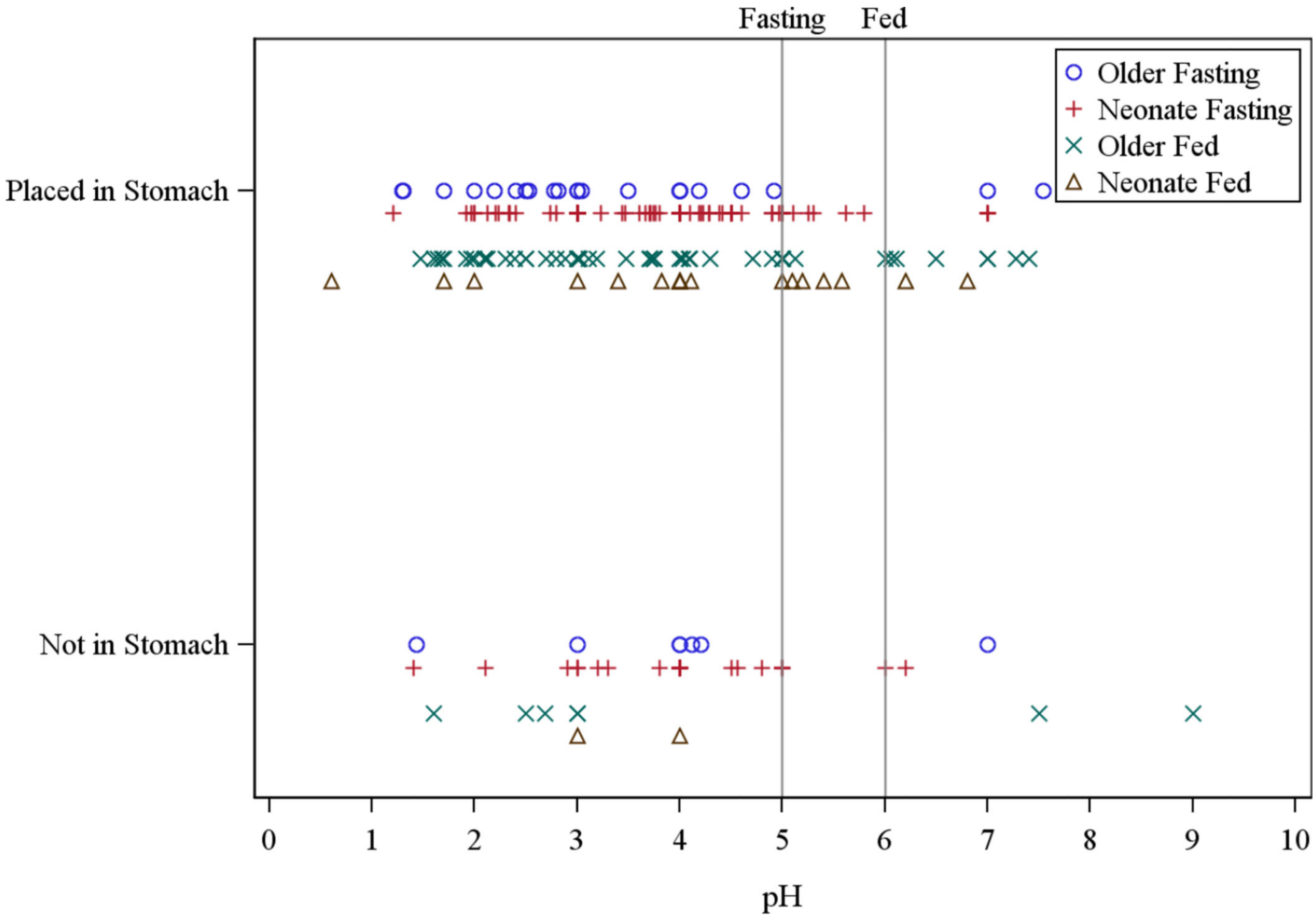

Figure 1.

Plot of pH readings based on whether or not the tube tip ended in the stomach identified by age group (neonate < 1 month/ older child, 1–215 months) and fed/fasting status.

Table 1

Comparison of participant characteristics both overall and by age group

	Overall (*N*=276)	**Neonates (<1 month) (*n* = 173)**	**Children (1-215 Months) (*n* = 103)**
Gender, *n* (%)			
Male	148 (53.6%)	95 (54.9%)	53 (51.5%)
Female	128 (46.4%)	78 (45.1%)	50 (48.5%)
Age[a] (months), *n* (%)			
<1	173 (62.7%)	173 (100%)	N/A
1–28	46 (44.7%)	N/A	46 (44.7%)
29–100	40 (38.8%)	N/A	40 (38.8%)
101–215	17 (16.5%)	N/A	17 (16.5%)
Term, *n* (%)			
Preterm	193 (69.9%)	167 (96.5%)	26 (25.2%)
Full term	83 (30.1%)	6 (3.5%)	77 (74.8%)
Length (cm), mean ± *SD*	64.0 ± 30.3	46.1 ± 3.9	94.2 ± 31.3
Race, *n* (%)			
Caucasian	171(62.0%)	85 (49.1%)	86 (83.5%)
African American	83 (30.1%)	74 (42.8%)	9 (8.7%)
Other	22 (8.0%)	14 (8.1%)	8 (7.8%)
Ethnicity, *n* (%)			
Hispanic	24 (8.7%)	18 (10.4%)	6 (5.8%)
Non-Hispanic	252 (91.3%)	155 (89.6%)	97 (94.2%)
Acid-inhibiting medication use, *n* (%)			
Receiving	41 (14.9%)	12 (6.9%)	29 (28.2%)
Not receiving	235 (85.1%)	161 (93.1%)	74 (71.8%)
Tube type, *n* (%)			
NG[b]	256 (92.8%)	155 (89.6%)	101 (98.1%)
OG[c]	20 (7.2%)	18 (10.4%)	2 (1.9%)
Tube placement, *n* (%)			
Stomach	213 (77.2%)	132 (76.3%)	81 (78.6%)
Esophagus	26 (9.4%)	16 (9.2%)	10 (9.7%)
GEJ[d]	23 (8.3%)	15 (8.7%)	8 (7.8%)
Duodenum	9 (3.3%)	7 (4.0%)	2 (1.9%)
Pylorus	5 (1.8%)	3 (1.7%)	2 (1.9%)

[a]Age corrected if < 36 months;

[b]NG: nasogastric;

[c]OG: orogastric;

[d]GEJ: gastroesophageal junction

Table 2

Ability of pH[a] testing to detect radiographically documented nasogastric/orogastric non-placement in all participating children stratified on feeding status

pH	Stomach	Non-Stomach	Sensitivity	Specificity	Positive predictive value:	Negative predictive value
Fasting Children[b]						
≤ 5	114	27	3/30 (10.0%)	114/124 (91.9%)	3/13 (23.1%)	114/141 (80.9%)
>5	10	3				
Fed Children (not fasting)[c]						
≤ 6	64	7	2/9 (22.2%)	64/73 (87.7%)	2/11 (18.2%)	64/71 (90.1%)
>6	9	2				

[a] If a pH monitor reading was available, it was used; if not, the pH strip reading was used.

[b] pH of aspirate obtained 154/186 cases (82.8%); Range = 1.2–7.5, *M*=3.8, *SD*=1.2

[c] pH of aspirate obtained 82/90 cases (91.1%); Range = 0.6–9.0, *M*=3.8, *SD*=1.7

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Table 3

Color of aspirate alone and combined with pH and documented nasogastric/orogastric placement in all participating children overall and stratified on feeding status

pH	Color	Stomach	GEJ/Esophagus	Duodenum/Pylorus	Total
			All Children (*N*=240)		
--	White	83	10	6	99 (41.3%)
--	Clear	42	8	1	51 (21.3%)
		33	4	3	40 (16.7%)
--	Tan	20	2	2	24 (10.0%)
--	Yellow	9	0	1	10 (4.2%)
--	Brown	6	1	1	8 (3.3%)
--	Bloody	4	0	0	4 (1.7%)
--	Green	3	1	0	4 (1.7%)
--	Other				
			Fasting children (*n*=153)		
≤ 5	White/Green/Tan	87	10	8	105 (68.6%)
	Other Colors	27	5	4	36 (23.5%)
>5	White/Green/Tan	6	1	0	7 (4.6%)
	Other Colors	3	2	0	5 (3.3%)
			Fed children (*n*=82)		
≤ 6	White/Green/Tan	25	2	1	28 (34.1%)
	Other Colors	39	3	1	43 (52.4%)
>6	White/Green/Tan	0	1	0	1 (1.2%)
	Other Colors	9	1	0	10 (12.2%)

Note. GEJ: gastroesophageal junction

Table 4

Summary of sensitivity, specificity, positive and negative predictive values of non-stomach placement for various conditions

	Sensitivity	Specificity	Positive predictive value	Negative predictive value
No aspirate	34.9	94.8	66.7	83.1
pH>5 in all fasting children	10.0	91.9	23.1	80.9
>5 in fasting neonates	8.7	92.2	20.0	81.7
>5 in fasting older children	14.3	90.9	33.3	76.9
pH>6 in all fed children	22.2	87.7	18.2	90.1
>6 in fed neonates	0.0	89.5	0.0	89.5
>6 in fed older children	28.6	87.0	22.2	90.4
Aspirate not colored white, green, or tan	42.5	60.0	17.5	83.9
pH>5 or aspirate not colored white, green or tan or both conditions in fasting children	40.0	70.7	25.0	82.9
pH>6 or aspirate not colored white, green or tan or both conditions in fed children	66.7	36.0	11.1	90.0